

## **CLAIMS**

**1. (previously presented)** A method for recovering high quality steel and non-ferrous metal products from contaminated molten steel scrap containing dissolved carbon and oxygen by in-line continuous processing of the liquid scrap in one or more vacuum desorbers employing physical desorption of impurities into an inert strip gas at typically around 3 mbar total pressure under dispersed contact conditions such as that afforded by melt irrigation of a packed bed within a desorption column/tower with counter current gas flow, using a special procedure for combating the disruptive effects of sub-surface nucleation and growth of CO bubbles, involving recirculation of molten steel product back into the basal region of the vacuum desorbers from liquid metal sumps at atmospheric pressure at a rate many times that of the actual rate of refined steel production and at least in the region of 20 tonnes per minute in conjunction with product metal removal from the liquid sumps, and thereby ensuring operability of the desorbers, continuity of flow of liquid metal as the dispersed phase and the availability of the full diffusional driving forces characteristic of non back-mixed gas/liquid contacting.

### **Claims 2 – 5 (canceled)**

**6. (previously presented)** The method as claimed in Claim 1, wherein the liquid scrap is formed continuously from solid contaminated steel scrap containing up to 1% Zn, up to 0.5% Cu and up to 0.4% Sn and then subsequently refined in a high temperature steelmaking circuit, the overall method comprising the steps of:-

(i) preheating the solid scrap in a protective gas atmosphere to separate out in sequence initially a molten zinc and then a molten aluminium by-product prior to the scrap being assimilated into a forced-circulated stream of molten scrap (liquid scrap) within a closed-loop melt circulation system.

(ii) overflowing, withdrawing or siphoning out continuously the liquid scrap from a melt circulation loop and incorporating it into a gas-lift pumping device which feeds the liquid scrap to the top of the first of two reduced pressure packed towers or similar vacuum desorbers, in which the liquid scrap is raised in temperature from near its liquidus temperature to a very much higher temperature typically in the region 1650 to 1780°C by electrical conductive heating or alternatively radiative heat transfer, whilst ensuring the liquid scrap being preheated behaves as a quiescent melt under a reduced ambient operating pressure, before finally being exposed to the full vacuum of about 3 mbar and then allowing it to irrigate the solid packing and flow downwards by gravity as rivulets or discrete droplets against an upward flow of strip gas typically at a pressure of 2-4 mbar, which volatilises elemental copper impurity dissolved in the liquid scrap, but only a relatively smaller amount of dissolved elemental tin, whilst itself becoming almost saturated with iron vapour;

(iii) withdrawing continuously via a barometric leg in the basal region of the desorber the gas-lift recirculated de-copperized liquid scrap containing now less than 0.05% Cu into an atmospheric pressure sump at a rate of at least 20 tonnes per minute and then overflowing it or otherwise transferring it continuously at the refined melt production rate into a second gas-lift pumping system employing a lift-gas to which elemental sulphur or gaseous

sulphur or sulphur compound gas has been added to the extent that the liquid scrap absorbs sulphur so that greater than the stoichiometric requirement for all the dissolved tin on average 0.2 – 0.4% Sn to potentially form stannous sulphide is provided;

(iv) admitting the liquid scrap into the top of a second reduced pressure packed tower or similar vacuum desorber operating at about 3 mbar total pressure and using electrical conductive heating, or alternatively radiative heat transfer , to increase the liquid scrap temperature up to typically 1600 – 1780°C prior to contacting the liquid scrap with an inert strip gas so that stannous sulphide is volatilized from the liquid scrap down to at least 0.01% Sn as it flows by gravity through the tower and then withdrawing continuously via a barometric leg as described previously the now de-tinned and de-copperized liquid scrap into an atmospheric pressure sump, from which the non-ferrous metal depleted liquid scrap is overflowed or siphoned continuously for further processing.

**Claims 7-9 (canceled)**

**10. (previously presented)** The method as outlined in Claim 6 with additional features incorporated if the steel scrap charged to the process contains organic coated steel based on PVC or other sources of chlorine contamination, these features comprising contacting pyrolysis gases evolved during scrap preheating with a spray of liquid aluminium droplets followed then by further contacting in a trickle irrigated packed bed employing a fused salt scrubbing medium containing sodium carbonate as the active ingredient in the interests of energy conservation, but more importantly to preclude hazardous dioxin formation.

**11. (previously presented)** The method as outlined in Claim 6 with the protective gas atmosphere referred to in Claim 2 (i) being preheated at high intensity by the optional inclusion of a molten aluminium droplet contactor based on molten aluminium both as a heat transfer medium and chemical desiccant, utilizing electromagnetic melt circulation together with commercially proven mechanical rotor/splash systems developed for the zinc/lead blast furnace.

**12. (previously presented)** The method as outlined in Claim 6, wherein the exit desorber strip gas in advance of selective condensation of copper and then tin recovery both as value-added products and which is almost completely saturated with iron vapour, is first subjected to direct contact iron condensation on recirculated liquid steel close to the liquidus temperature, employing residual unmelted steel shells for melt containment, stabilized by generation of high pressure steam for power generation by radiation from the outer surfaces of the retained solid steel shell, which surrounds an irrigated packed bed and its associated gas-lift liquid steel melt circulation system.

## Claims

1. A method for recovering high quality steel and non-ferrous metal products from contaminated molten steel scrap containing dissolved carbon and oxygen by in-line continuous processing of the liquid scrap in one or more vacuum desorbers employing physical desorption of impurities into an inert strip gas at typically around 3 mbar total pressure under dispersed contact conditions such as that afforded by melt irrigation of a packed bed within a desorption column/tower with counter current gas flow, using a special procedure for combating the disruptive effects of sub-surface nucleation and growth of CO bubbles, involving recirculation of molten steel product back into the basal region of the vacuum desorbers from liquid metal sums at atmospheric pressure at a rate many times that of the actual rate of refined steel production and at least in the region of 20 tonnes per minute in conjunction with product metal removal from the liquid sums, and thereby ensuring operability of the desorbers, continuity of flow of liquid metal as the dispersed phase and the availability of the full diffusional driving forces characteristic of non back-mixed gas/liquid contacting.
  
2. The method as claimed in Claim 1, wherein the liquid scrap is formed continuously from solid contaminated steel scrap containing up to 1% Zn, up to 0.5% Cu and up to 0.4% Sn and then subsequently refined in a high temperature steelmaking circuit, the overall method comprising the steps of:-
  - (i) preheating the solid scrap in a protective gas atmosphere to separate out in sequence initially a molten zinc and then a molten aluminium by-product prior to the scrap being assimilated into a forced-circulated stream of molten scrap (liquid scrap) within a closed-loop melt circulation system.
  
  - (ii) overflowing, withdrawing or siphoning out continuously the liquid scrap from a melt circulation loop and incorporating it into a gas-lift pumping device which feeds the liquid scrap to the top of the first of two reduced pressure packed towers or similar vacuum desorbers, in which the liquid scrap is raised in temperature from near its liquidus temperature to a very much higher temperature typically in the region 1650 to 1780°C by electrical conductive heating or alternatively radiative heat transfer, whilst ensuring the liquid scrap being preheated behaves as a quiescent melt under a reduced ambient operating pressure, before finally being exposed to the full vacuum of about 3 mbar and then allowing it to irrigate the solid packing and flow downwards by gravity as rivulets or discrete droplets against an upward flow of strip gas typically at a pressure of 2-4 mbar, which volatilises elemental copper impurity dissolved in the liquid scrap, but only a relatively smaller amount of dissolved elemental tin, whilst itself becoming almost saturated with iron vapour;
  
  - (iii) withdrawing continuously via a barometric leg in the basal region of the desorber the gas-lift recirculated de-copperized liquid scrap containing now less than 0.05% Cu into an atmospheric pressure sum at a rate of at least 20 tonnes per minute and then overflowing it or otherwise transferring it continuously at the refined melt production rate into a second gas-lift pumping system employing a lift-gas to which elemental sulphur or gaseous sulphur or sulphur compound gas has been added to the extent that the liquid scrap absorbs sulphur so that greater than the stoichiometric requirement for all the dissolved tin on average 0.2 – 0.4% Sn to potentially form stannous sulphide is provided;

(iv) admitting the liquid scrap into the top of a second reduced pressure packed tower or similar vacuum desorber operating at about 3 mbar total pressure and using electrical conductive heating, or alternatively radiative heat transfer , to increase the liquid scrap temperature up to typically 1600 – 1780°C prior to contacting the liquid scrap with an inert strip gas so that stannous sulphide is volatilized from the liquid scrap down to at least 0.01% Sn as it flows by gravity through the tower and then withdrawing continuously via a barometric leg as described previously the now de-tinned and de-copperized liquid scrap into an atmospheric pressure sump, from which the non-ferrous metal depleted liquid scrap is overflowed or siphoned continuously for further processing.

3. The method as outlined in Claim 2 with additional features incorporated if the steel scrap charged to the process contains organic coated steel based on PVC or other sources of chlorine contamination, these features comprising contacting pyrolysis gases evolved during scrap preheating with a spray of liquid aluminium droplets followed then by further contacting in a trickle irrigated packed bed employing a fused salt scrubbing medium containing sodium carbonate as the active ingredient in the interests of energy conservation, but more importantly to preclude hazardous dioxin formation.

4. The method as outlined in Claim 2 with the protective gas atmosphere referred to in Claim 2 (i) being preheated at high intensity by the optional inclusion of a molten aluminium droplet contactor based on molten aluminium both as a heat transfer medium and chemical desiccant, utilizing electromagnetic melt circulation together with commercially proven mechanical rotor/splash systems developed for the zinc/lead blast furnace.

5. The method as outlined in Claim 2, wherein the exit desorber strip gas in advance of selective condensation of copper and then tin recovery both as value-added products and which is almost completely saturated with iron vapour, is first subjected to direct contact iron condensation on recirculated liquid steel close to the liquidus temperature, employing residual unmelted steel shells for melt containment, stabilized by generation of high pressure steam for power generation by radiation from the outer surfaces of the retained solid steel shell, which surrounds an irrigated packed bed and its associated gas-lift liquid steel melt circulation system.